



# Standard Test Method for Resistivity of Metallically Conducting Resistance and Contact Materials<sup>1</sup>

This standard is issued under the fixed designation B63; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope

1.1 This test method covers the determination, to a precision of 2 %, of the electrical resistivity of materials used in resistors, heating elements, and electrical contacts, as well as products of powder metallurgy processes which are used for other purposes.

NOTE 1—For determining the resistivity of electrical conductors, see Test Method B193.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer; to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

[B193 Test Method for Resistivity of Electrical Conductor Materials](#)

## 3. Terminology

### 3.1 Definitions:

3.1.1 *resistivity, n*—that property of a material which determines its resistance to the flow of an electric current, expressed as:

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.10 on Thermostat Metals and Electrical Resistance Heating Materials.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

$$\rho = RA/L \quad (1)$$

where  $R$  is the resistance in ohms of a specimen of the material of uniform cross section  $A$  and of a length  $L$ . In reporting values of resistivity under this test  $A$  shall be expressed in square centimeters and  $L$  in centimeters. Resistivity is measured in micro ohm-meter. English units of ohms circular mil per foot are expressed as:

$$\rho = 12 \times 10^6 R A/0.7854 L \quad (2)$$

where:

$R$  = resistance in ohms

$A$  = uniform cross section area in square inches

$L$  = length in inches

## 4. Significance and Use

4.1 In the case of materials for resistors and heating elements, a knowledge of resistivity is important in determining whether wire or strip of a specified area of cross section and length will have a required resistance. It serves as one basis for the selection of materials for specific applications and its measurement is a necessary acceptance test for resistance materials.

4.2 In the case of materials for electrical contacts, the measurement of resistivity can serve as a test for uniformity of materials of nominally the same composition and structure.

## 5. Apparatus

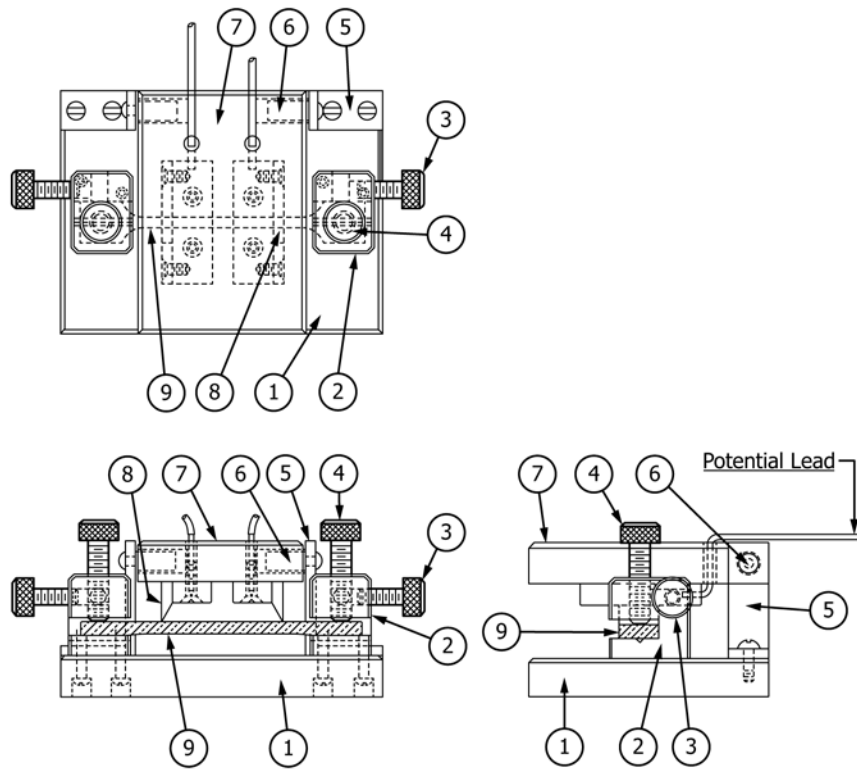
5.1 Means for applying current and voltage terminals to the specimen are specified in Section 9. An optional suitable specimen holder for nonductile materials is shown in Fig. 1.

5.2 A suitable bridge, potentiometer, digital ohmmeter, or equivalent, with necessary accessories for making resistance measurements with a limit of error of less than 0.5 %.

5.3 Means for measuring the dimensions of the specimen, adequate to determine its length and its mean area of cross section, each within 0.5 %.

## 6. Test Specimen

6.1 *Ductile Materials*—The test specimen for ductile materials, including those used for contacts, shall be in the



Item	Description	Dimensions, in. (mm)	Material	Number Required
1	Base block	1/2 by 3 by 4 (12.7 by 76.2 by 101.6)	micarta	1
2	Clamp block	3/4 by 1 by 1 (19.0 by 25.4 by 25.4)	copper	2
3	Current lead clamp screw, knurled head	1/2 by 3/16	brass	2
4	Specimen clamp screw, knurled head	1/4 in. by 40 by 1 in.	brass	2
5	Pivot bracket	1/2 by 1 1/16 by 1 7/16 (12.7 by 23.8 by 36.5)	steel	2
6	Pivot	...	steel	2
7	Pivot block	1/2 by 2 3/32 by 3 (12.7 by 53.2 by 76.2)	micarta	1
8	Potential knife-edge	...	steel	2 sets
9	Specimen being tested	...	...	...

NOTE 1—Contact surfaces must be clean and free of visible oxide.

FIG. 1 Specimen Holder for Nonductile Materials

form of a wire or a strip. In order to determine the resistivity with a precision of 2 %, it is necessary that the resistance, cross-sectional area, and length shall be measured with a limit of error within 0.5 %. To ensure this limit of error each test specimen shall conform to the following:

6.1.1 It shall have a length of at least 0.5 ft (15 cm) between potential probes.

6.1.2 It shall have a resistance of at least 0.001 Ω.

6.1.3 If the cross section is to be determined by direct measurement, the diameter of a wire specimen or the thickness of a strip specimen shall not be less than the limits defined by the 0.5 % criteria of 6.1, and this dimension throughout the length of the specimen shall not vary by more than 3 %.

6.1.4 It shall show no surface cracks or other defects observable with normal vision, and shall be free from surface oxide.

6.2 *Nonductile Materials*—The test specimen for nonductile materials shall be made in accordance with Fig. 2 if the

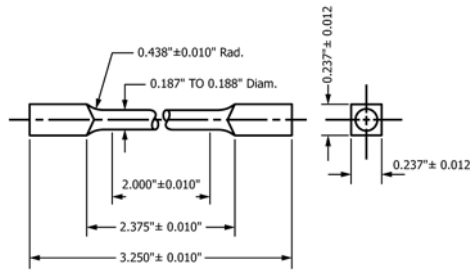
material is readily machinable. For materials which are not readily machinable, such as those containing graphite, a flat strip may be used as a test specimen. In order to determine the resistivity with a precision of 2 %, each specimen shall conform to the following:

6.2.1 The diameter of a specimen (Fig. 2), or the thickness and width of a strip specimen, shall be uniform within 1 %.

6.2.2 It shall show no surface cracks or other defects observable with normal vision, and shall be free from surface oxide.

## 7. Length Measurements

7.1 The length may be measured by any scale which will give an accuracy of 0.5 % in the length measured. In case potential leads are used, the length shall be taken between the potential contacts. In the direction of the length of specimen, the dimension of each potential contact, including soldering surface or clamp contact area, shall not be more than 0.5 % of



NOTE 1—Metric equivalents are as follows.

in.	mm	in.	mm
0.010	0.25	0.438	11.12
0.012	0.30	2.000	50.80
0.187	4.75	2.375	60.32
0.188	4.78	3.250	82.55
0.237	6.01		

FIG. 2 Resistivity Test Specimen for Machinable Nonductile Materials

the distance between the potential contacts. In the case of the specimen holder for nonductile materials shown in Fig. 1, the distance between the potential contacts may be found by measuring from the outside flat of one potential knife edge to the outside flat of the other. A micrometer or other suitable means shall be used for measuring this length.

### 8. Cross-Sectional Area Measurements

8.1 In general, the diameter of a specimen of circular cross section, or the thickness and width of a strip specimen, shall be determined by micrometer measurements, and a sufficient number of measurements shall be made to obtain the mean cross section to within 0.5 %.

8.2 In case the diameter of the cylinder or the thickness of the strip cannot be measured to give the above accuracy with the micrometer available, determine the cross section from the weight, density, and length of specimen.

8.3 When the density is unknown, it may be determined as follows:

8.3.1 For nonporous materials first weigh a sample of at least 10 g in air and then in water. The density in grams per cubic centimetre is equivalent to the weight in air divided by the loss of weight due to submergence in water. The water shall be at room temperature to avoid errors due to convection currents. For the accuracy required, no corrections are necessary for the temperature of the water or for the buoyancy of the air. However, exercise care to remove all air bubbles from the specimen when weighing it in water. To remove air bubbles from a specimen of fine wire, dip the wire, in the form of a loosely wound coil, in alcohol and rinse in water before immersing it in the water to be used in weighing. Then calculate the density from the following equation:

$$D = B/(B - E) \quad (3)$$

where:

$D$  = density, g/cm<sup>3</sup>

$B$  = weight of specimen in air, g

$E$  = weight of specimen in water, g

The cross-sectional area,  $A$ , in square centimeters, may be found from the equation:

$$A = (B - E)/L \quad (4)$$

8.3.2 For porous materials such as products of powder metallurgy, weigh a specimen of at least 10 g in air. Immerse the specimen for at least 4 h in oil (viscosity of approximately 200 SUS at 37.8°C (100°F), held at a temperature of 82.2 ± 5.5°C (180 ± 10°F). Then cool the specimen to room temperature by immersing it in oil at room temperature. After removing excess oil from the specimen by means of a soft cloth, weigh the specimen in air and then in water. Calculate the density from the equation:

$$D = B/(C - E) \quad (5)$$

where:

$D$  = density, g/cm<sup>3</sup>

$B$  = weight of the unimpregnated specimen in air, g

$C$  = weight of the specimen impregnated with oil (in air), g

$E$  = weight of the impregnated specimen in water, g

The cross-sectional area,  $A$ , in square centimetres, may be found from the equation:

$$A = (C - E)/L \quad (6)$$

### 9. Leads

9.1 Specimens with a resistance of less than 10 Ω shall be provided with both current and potential leads. The minimum distance between each potential contact and the adjacent current lead shall be at least three times the diameter of the wire or the width of the strip. Current shall be introduced into the specimen with current leads amply large to minimize heating of the specimen. Specimens with a resistance greater than 10 Ω do not require potential leads, though they may be used, if desired.

### 10. Resistance Measurements

10.1 Resistance of specimens provided with potential leads shall be measured with a Kelvin bridge, potentiometer, digital ohmmeter, or equivalent capable of measuring the resistance between the potential contacts with a limit of error within 0.5 %. Specimens with a resistance of more than 1 Ω may be measured with a limit of error within 0.5 % by means of a suitable Wheatstone bridge.

### 11. Heating of Specimen

11.1 In all resistance measurements, the measuring current raises the temperature of the specimen above that of the surrounding medium. If this is sufficient to change the resistance by 0.5 %, a correction shall be made. In general, the smallest current that will give the sensitivity necessary to measure to 0.5 % of the resistance shall be used. A convenient test to determine whether a correction should be applied is to increase the current to 1.4 times the value it had when the measurement was made (Note 2) and then to measure the resulting change in resistance. If this change is as large as 0.5 % of the measured value, a correction should be made. For a material which has a positive temperature coefficient of

resistance, the resistance at the temperature of the surrounding medium shall be obtained by subtracting the measured change from the resistance as measured with the smaller current. For material with a negative temperature coefficient, this difference shall be added to the resistance obtained by measurements with the smaller current.

NOTE 2—Increasing the current to 1.4 times the value it had when the measurement was made serves to very nearly double the heating effect, and, for small changes in temperature, the rise in temperature.

11.2 Measurements are to be in a controlled temperature environment.

## 12. Report

12.1 Report the following information:

- 12.1.1 Identification of test specimen,
- 12.1.2 Material type,
- 12.1.3 Temperature of surrounding medium,
- 12.1.4 Length of specimen used,
- 12.1.5 Method of obtaining cross-sectional area:

12.1.5.1 *If by micrometer*, a record of all micrometer readings, including average values and calculated cross-sectional area,

12.1.5.2 *If by weighing*, a record of length, mass and density determinations and calculated cross-sectional area,

12.1.6 Method of measuring resistance,

12.1.7 Value of resistance,

12.1.8 Calculated value of electrical resistivity, and

12.1.9 Previous mechanical and thermal treatments. (Since the resistivity of a material usually depends upon them, these shall be stated whenever the information is available.)

## 13. Precision and Bias

13.1 The precision of this test method is within 2 %.

13.2 The bias of this test method is less than 1 %.

## 14. Keywords

14.1 contact materials; electrical conductors; heating elements; resistivity; resistors; specific resistance

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